RADIATION PHYSICS NOTE #94

Fermilab's Radiological Calibration Intercomparison

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I. INTRODUCTION

The purpose of the DOE intercomparison program is: to provide participation in the MQA program which helps in testing radiation fields using standard measurement techniques and to supply calibrated instruments or sources. This program also helps in identifying current problems associated with radiation calibration measurements and provides a forum addressing existing and potential radiological calibration problems by holding periodic workshops. The ES&H Section's participation was to evaluate the calibration of 137-8.1-1, 137-7.1-1, 137-6.1-1, 137-3.5-1, Am241Be-7.2-1 and Cf252-7.2-1 sources. Fermilab's ES&H Section has participated in a similar investigation in 1987[1].

II. EQUIPMENT AND PROCEDURE

Battle Pacific Northwest Laboratories (PNL) in Richland, Washington supplied the equipment for this study. The instrument package included an electrometer to measure integrated charge collected by ionization chambers, a thin walled PM-30 ion chamber to measure exposure from calibrated photon sources, a 1000cc tissue-equivalent ion chamber (TEIC) to measure total kerma from neutron sources, a Geiger-Mueller (GM) counter to measure the photon components of the sources, five TLD dosimeters to measure photon and/or neutron dose by intercomparing with PNL TLD response, a battery pack power supply, a portable NIMBIN, a scaler counter/timer, and a NIMBIN power supply.

The measured sensitivities of the GM detector, PM-30 ion chamber and the 1000cc ion chamber were compared to the PNL values to check on the accuracy with which the activity of the Fermilab sources is known. The extrapolated source activity -- corrected for decay to the measurement day -- was used in the calculation. The three TLD dosimeters were placed on an arc of 50 cm radius with an unmoderated ^{252}Cf source[2] (Cf252-7.2-1) at the center of the arc. The TLDs were irradiated in this configuration for approximately 8 hours for a neutron dose of 250 mrem each. PNL will develop or read these badges and compare the results to their own irradiation and will inform us of the results. The appendix contains copies of the data sheets.

III. RESULTS

The GM detector was exposed to 137-7.1-1 and 137-6.1-1 sources at two different distances each:

Source: 137-7.1-1
Distance: 1 m
Measurement interval: 10 sec.

Exposure rate (1 m): 3.308 R/hr
Number of measurements: 12
Response: 6.297×10^{-7} R/pulse

Source: 137-7.1-1
Distance: 2 m

Exposure rate (1 m): 3.308 R/hr
Number of measurements: 12

Measurement interval: 10 sec.

Response: 6.062×10^{-7} R/pulse

Source: 137-6.1-1
Distance: 1 m
Measurement interval: 20 sec.

Exposure rate (1 m): 385.8 mR/hr
Number of measurements: 12
Response: 6.173×10^{-7} R/pulse

Source: 137-6.1-1
Distance: 2 m
Measurement interval: 20 sec.

Exposure rate (1 m): 385.8 mR/hr
Number of measurements: 12
Response: 6.041×10^{-7} R/pulse

The PM-30 ion chamber was exposed to the cesium sources 137-8.1-1, 137-7.1-1 and 137-6.1-1 at a distance of one meter from the detector. All tests were done with the buildup cap on the PM-30. The ambient temperature and pressures were recorded for density corrections:

$$\text{Air density correction factor} = \frac{760\ (\text{torr}) \times (273.15 + \text{T}(^{\circ}C))}{\text{p(torr)} \times 295^{\circ}\text{K}},$$

Source: 137-6.1-1
Exposure rate: 385.8 mR/hr
Elec. corr. factor: 1.009
Ave. drift: 3.150×10^{-5}nC/sec
Cham. resp. = 1.129×10^{8} R/C

Temperature: 19.1°C
Pressure: 757.8 torr
Air density corr: 0.993
Ave. current: 97.87×10^{-5}nC/sec

Source: 137-7.1-1
Exposure rate: 3030.8 mR/hr
Elec. corr. factor: 1.009
Ave. drift: 2.50×10^{-5} nC/sec
Cham. resp. = 1.111×10^{8} R/C

Temperature: 19.0°C
Pressure: 758. torr
Air density corr: 0.992
Ave. current: 7.595×10^{-3} nC/sec

Source: 137-8.1-1
Exposure rate: 23.789 R/hr
Elec. corr. factor: 1.009
Ave. drift: 2.40×10^{-5}nC/sec
Cham. resp. = 1.125×10^{8} R/C

Temperature: 18.8°C
Pressure: 758.5 torr
Air density corr: 0.991
Ave. (current-drift): 5.875×10^{-2}nC/sec

The neutron response of the 1000cc TEIC was measured by first exposing it to an AmBe source (241Be-7.2-1) which radiates a mixed neutron and gamma field. The response of the TEIC to the photon component of the AmBe source, is needed for subtraction from the mixed field response. For this purpose three additional measurements were done: 1) the GM counter was exposed to the same AmBe source and its photon response was calculated, 2) the GM counter was exposed to a NBS-calibrated pure gamma source (137-3.5-1), 3) the TEIC was exposed to the same gamma source. The responses of the two detectors to the NBS source were used to normalize the response of the GM detector -- to the AmBe source -- to that of the TEIC's response to the photon component of the AmBe source. The results are shown in the following table:

Detector: TEIC
Dose eq. rate: 21.695 mrem/hr
Ave. drift: 2.92×10^{-14} C/sec
Signal: 2.914×10^{-13}C/sec

Source: Am241Be-7.2-1
Elec. corr. factor: 1.009
Ave.current: 3.18×10^{-13} C/sec

Detector: GM

Source: Am241Be-7.2-1

GM response: 6.168 X 10^{-7} R/pulse
Measured rate: 8.971 X 10^{-4}R/hr

Ave. count rate: 0.404 pulse/sec

Detector: TEIC
Exposure rate: 1.256 X 10^{-3} R/hr
Ave. drift: 1.90 X 10^{-14} C/sec
Signal: 11.52 X 10^{-14} C/sec

Source: 137-3.5-1
Elec. corr. factor: 1.009
Ave.current:1.140x10^{-13}C/sec
TEIC gamma response:3.034x10^{6} R/C

Detector: GM
Exposure rate: 1.256 X 10^{-3} R/hr
Ave. count rate: 0.577 pulse/sec

Source: 137-3.5-1
GM response: 6.168 X 10^{-7}R/pulse
Measured rate: .281 X 10^{-3}R/hr

To calculate the response of the TEIC to the neutrons from the AmBe source the following data from the above set were used:

$\dot{D}_n$ (*AmBe* source neutron dose equivalent rate) $= 6.026\times10^{-6} rem/\sec$,

$\dot{S}_{n+\gamma} = 2.914\times10^{-13} C/\sec$, $\dot{R}_{\gamma-GM} = 0.577 pulse/\sec$, $\dot{R}_{\gamma-TEIC} = 1.143\times10^{-13} C/\sec$,

$\dot{R}_{n+\gamma-GM} = 0.404\ pulse/\sec$,,

$\dot{R}_{n+\gamma-TEIC} = \dot{D}_n\dot{R}_{n-TEIC} + \dot{D}_\gamma\dot{R}_{\gamma-TEIC}$

$\dot{R}_{n+\gamma-GM} = \quad + \dot{D}_\gamma\dot{R}_{\gamma-GM}$

$$\therefore\ \dot{R}_{n+\gamma-TEIC} = \dot{D}_n\dot{R}_{n-TEIC} + \frac{\dot{R}_{n+\gamma-GM}}{\dot{R}_{\gamma-GM}}\dot{R}_{\gamma-TEIC}$$

$$\dot{S}_\gamma(\text{TEIC AmBe } \gamma-response) = \dot{R}_{\gamma-TEIC}\times\frac{\dot{R}_{n\gamma-GM}}{\dot{R}_{\gamma-GM}} = 1.143\times10^{-13}\times\frac{0.404}{0.577} = 0.800\times10^{-13} C/\sec,$$

$$\dot{S}_n(\text{TEIC AmBe n - response}) = \dot{S}_{n+\gamma} - \dot{S}_\gamma = 2.914\times10^{-13} - 0.800\times10^{-13} = 2.114\times10^{-13} C/\sec,$$

$$\text{TEIC neutron sensitivity} = \frac{\dot{D}_n}{\dot{S}_n} = \frac{6.026\times10^{-6} rem/\sec}{2.114\times10^{-13} C/\sec} = 2.851\times10^{7} rem/C.$$

The g-fraction of the AmBe source, $\dot{S}_\gamma/\dot{S}_{n+\gamma}$,from the above results is 27.5%.

IV. CONCLUSION

The average of the four GM measurements gave a response of 6.143 X 10^{-7} ±1.9% R/pulse, which compares very well with the given value of 6 X 10^{-7} ±20% R/pulse. The three measurements with the PM-30 produced an average response of 1.122 X 10^{8} ±0.9% R/coul. which is in good agreement with the PNL quoted response of 1x10^{8} ±20% R/coul. The response of the 1000cc TEIC to photons was measured to be 3.034 X 10^{6} R/coul., which is in very good agreement with the PNL value of 3 X 10^{6} ±20% R/Coul. The neutron response of the TEIC to the unmoderated AmBe source was measured to be 2.851 X 10^{7} rem/Coul. which is 43% different from the quoted value of 2 X 10^{7} rem/Coul. There are several reasons for this apparent difference; PNL has used a ^{252}Cf- neutron source, which produces neutrons with one half the average energy of the AmBe-source's neutrons, and TEIC response is not energy independent. Furthermore, the Cs photon source used to deduce and normalize the TEIC photon response produces photons that are about seven times less energetic than most of the photons from the AmBe source. The

variation of the photon response with energy would effect the subtraction of the photon response from the photon-plus-neutron response.

PNL sensitivities are given with an uncertainty of ±20%. However, the activity of the sources used in this study are known to better accuracy than ±20%, and any disagreement with the quoted numbers outside this range indicates a mistake in procedure. The quoted sensitivities can not be used to improve the calibrations of our sources.

V. REFERENCES

1. R. Dagenias, M. Sanchez and R. Allen, Radiation Physics Note #66 , 1987.

2. R. B. Schwartz, ISO 8529 (1989), used for ^{252}Cf source, neutron spectrum strengths.

VI. APPENDIX

1) TLD exposure information sheet.

2) GM counter response measurement in a photon field.

3) PM-30 ionization chamber measurement.

4) Neutron field measurement using a tissue-equivalent ion chamber.

Fermilab

TLD Exposure Information Sheet

Source 1:

Exposure Badge I.D.: 1.) 320 2.) 321 3.) 322

Control Badge I.D.: 1.) 323 2.) 324

Irradiation Date: 2/26/'92

Source Type: ^{252}Cf (Unmoderated) ~~(If X-ray give energy in keV)~~

Distance: 50 cm

Exposure (check one): ✓ In Air ____ On Phantom

Given Dose Equivalent (mrem): 250. ≡ 22.9 mrad

Operator's Name: Fred Krueger / Kamran Vaziri

Source 2:

Exposure Badge I. D.: 1.)____ 2.) ____ 3.) ____

Irradiation Date: _____

Source Type: _____ (If X-ray give energy in keV)

Distance: _____

Exposure (check one): ____ In Air ____ On Phantom

Given Dose Equivalent (mrem): _____

Operator's Name: _____

GM COUNTER RESPONSE MEASUREMENT IN A PHOTON FIELD

Version: Feb. 15, 1991

GM Counter (s/n) GM525

HV Supply (s/n) 1679 26

Voltage +500

Timer/Counter (s/n) IR0073 20

Date 2/10/'92

Photon Source (ID#) 137-7.1-1

Source Rate, $\dot{X}$ 3.308 R/hr@1.m

Distance 1. m

Operator Fred Krueger / Kamran Vaziri

CAP OFF

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	10	13335	1333.5
2	"	13,268	1326.8
3	"	13,311	1331.1
4	"	13,315	1331.5
5	"	13,474	1347.4
6	"	13,279	1327.9
7	"	13233	1323.3
8	"	13260	1326.0
9	"	13539	1353.9
10	"	13505	1350.5
"	"	13457	1345.7
"	"	13451	1345.1

Ave. Count rate, $\dot{R}$ = 1336.9 Std. Deviation = 10.8 counts/sec

Reported Response 6.297×10^{-7} R/pulse $\pm 0.042 \times 10^{-7}$ R/pulse

Response = $\dot{X} * 3600 / \dot{R}$

GM COUNTER RESPONSE MEASUREMENT IN A PHOTON FIELD

Version: Feb. 15, 1991

GM Counter (s/n) GM525

HV Supply (s/n) 1679 26

Voltage +500

Timer/Counter (s/n) IR00732Ø

Date 2/10/'92

Photon Source (ID#) 137-6.1-1

Source Rate, $\dot{X}$ 385.816 mR/hr @1.m

Distance 2.m

Operator Fred Krueger/Kamran Vaziri

GAP

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	100	4473	
2	100	4300	
3	100	4391	
4	100	4460	
5	100	4434	
6	100	4388	
7	100	4432	
8	100	4495	
9	100	4517	
10	100	4471	
11	100	4462	
12	100	4412	

Ave. Count rate, $\dot{R}$ = 4436.25 Pulse/100sec Std. Deviation = 58.24 Pulse/100sec

Reported Response 6.041 $\times 10^{-7}$ R/Pulse $\pm$ 0.066 $\times 10^{-7}$ R/Pulse

Response = $\dot{X}$ * 3600 / $\dot{R}$

GM COUNTER RESPONSE MEASUREMENT IN A PHOTON FIELD

Version: Feb. 15, 1991

GM Counter (s/n) GM525

HV Supply (s/n) 167926

Voltage +500

Timer/Counter (s/n) IR007320

Date 2/10/'92

Photon Source (ID#) 137-7.1-1

Source Rate, $\dot{X}$ 3.308 R/hr @1.m

Distance 2. m

Operator Fred Krueger / Kamran Vaziri

CAP OFF

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	10 Sec	3488	
2	"	3448	
3	"	3429	
4	"	3472	
5	"	3521	
6	"	3384	
7	"	3503	
8	"	3511	
9	"	3573	
10	"	3407	
11	"	3447	
12	"	3478	

Ave. Count rate, $\dot{R}$ = 3472 Std. Deviation = 53

Reported Response 6.062×10^{-7} R/pulse $\pm 0.077 \times 10^{-7}$ R/pulse

Response = $\dot{X} * 3600 / \dot{R}$

GM COUNTER RESPONSE MEASUREMENT IN A PHOTON FIELD

Version: Feb. 15, 1991

GM Counter (s/n) GM525 Photon Source (ID#) 137-7.1-1

HV Supply (s/n) 1679 26 Source Rate, $\dot{X}$ 3.308 R/hr @1.m

Voltage +500 Distance 2. m

Timer/Counter (s/n) IR0073 20 Operator Fred Krueger / Kamran Vaziri

Date 2/18/'92

CAL (1)

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	10	3322	
2	"	3332	
3	"	3450	
4	"	3349	
5	"	3375	
6	"	3327	
7	"	3349	
8	"	3330	
9	"	3355	
10	"	3382	
11	"	3389	
12	"	3338	

Ave. Count rate, $\dot{R}$ = 3358.2 counts/sec Std. Deviation = 36.4 counts/sec

Reported Response 6.267×10^{-7} R/pulse $\pm 0.057 \times 10^{-7}$ R/pulse

Response = $\dot{X} * 3600 / \dot{R}$

GM COUNTER RESPONSE MEASUREMENT IN A PHOTON FIELD

Version: Feb. 15, 1991

GM Counter (s/n) GM525

HV Supply (s/n) 1679.26

Voltage + 500 volts

Timer/Counter (s/n) IR0073 20

Date 2/10/92

Photon Source (ID#) 137-6.1-1

Source Rate, $\dot{X}$ 385.816 mR/hr @ 1. m

Distance 1. m.

Operator Fred Krueger / Kamran Vaziri

CAP OFF

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)
1	20	3477	
2	"	3430	
3	"	3528	
4		3533	
5	"	3492	
6	"	3498	
7	"	3529	
8		3429	
9	"	3451	
10		3496	
11		3571	
12		3488	

Ave. Count rate, $\dot{R}$ = 3472/20sec Std. Deviation = 52.6/20sec

Reported Response 6.173×10^{-7} R/pulse $\pm 0.078 \times 10^{-7}$ R/pulse

Response = $\dot{X} * 3600 / \dot{R}$

PM-30 IONIZATION CHAMBER MEASUREMENT

Version: November 21, 1986

Chamber (s/n) C1130.5281
Voltage ±300
Electrometer (s/n, cal. exp. date) 14356, 11/20/91 /NS
Elec. Corr. Factor, Ce 1.009
Elec. Range 0.2 nC
(e.g. nC or 10^{-10} etc.)
Humidity (% rel.) 48%
Date of Measurement 2/11/92
Operator Fred Krueger / Kamran Vaziri

Source (ID#) 137-6.1-1
Distance 1 m
Stop watch (s/n, cal. exp. date) CASIO
Buildup Cap (y or n) Y
Temperature (deg-C) 19.1°C
Pressure (torr) 757.8 mm
Air Density Corr. 0.993
* Ctp = 760 * (273 + T) / P / 295 *

offset = -60 fC | Drift			offset = -60 fC | Irradiation		
Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere	Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere
100	+3240 fC		100	97020 fC	
100	3060 fC		100	97130 fC	
	3150 fC/100 sec		100	99160 fC	
			100	98660 fC	
			100	98600 fC	
			100	96670 fC	
				97873.3 ± 1051.8 fC/100 sec	

Average Drift, $\bar{D}$ = 3.150×10^{-5} nC/s Average Current, $\bar{I}$ = $(97.873_3 \pm 1.051_4) \times 10^{-5}$ nC/s

Signal, S = ($\bar{I}$ − $\bar{D}$) * Ctp * Ce

Delivered Exposure Rate, $\dot{X}$ 385.816 mR/hr Chamber Response 1.129×10^{8} R/C

*** Chamber Response = $\dot{X}$ / S ***

PM-30 IONIZATION CHAMBER MEASUREMENT

Version: November 21, 1986

Chamber (s/n) C1130.5281
Voltage +300
Electrometer (s/n. cal. exp. date) 14356, 11/20/91, NS
Elec. Corr. Factor, Ce 1.009
Elec. Range 2 nC
(e.g. nC or 10^{-10} etc.)
Humidity (% rel.) 48%
Date of Measurement 2/11/92
Operator F. Kruger / K. Vaziri

Source (ID#) 137-7.1-1
Distance 1m
Stop watch (s/n. cal. exp. date)
Buildup Cap (y or n) Y
Temperature (deg-C) 19.C°
Pressure (torr) 758 torr
Air Density Corr. 0.992
* Ctp = 760 * (273 + T) / P / 295 *

offset = -60 fC / Drift			Irradiation		
Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere	Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere
200	2990fC		100	0.7518 nC	
				0.7596 nC	
				0.7698 nC	
				0.7574 nC	
				0.7625 nC	
				0.7602 nC	
				0.7586 nC	
				0.7620 nC	
				0.7552 nC	
				0.7615 nC	
100	0.0033 nC			Ave = 0.7595 ± 0.0027 nC	
100	0.0015 nC				
100	0.0017 nC				
100	.0033 nC				
	Ave = 0.0025 ± 0.0010 nC				

$I_{suppress}$
I_n

Average Drift, $\bar{D}$ = 0.0025 nC/100s Average Current, $\bar{I}$ = 0.7595 nC/100s

Signal, $S = (\bar{I} - \bar{D}) * Ctp * Ce$

Delivered Exposure Rate, $\dot{X}$ 84.189×10^{-5} R/s Chamber Response 1.1107×10^{8} R/s

*** Chamber Response = $\dot{X}$ / S ***

PM-30 IONIZATION CHAMBER MEASUREMENT

Version: November 21, 1986

Chamber (s/n) C1130.5281
Voltage +300 V
Electrometer (s/n, cal. exp. date) 14356, 11/20/91, NS
Elec. Corr. Factor, Ce 1.009
Elec. Range 20 nC
(e.g. nC or 10^{-10} etc.)
Humidity (% rel.) 48%
Date of Measurement 2/11/92
Operator ___

Source (ID#) 137-8.1-1
Distance 1 meter
Stop watch (s/n, cal. exp. date) ___
Buildup Cap (y or n) Y
Temperature (deg-C) 18.8 °C
Pressure (torr) 758.5 torr
Air Density Corr. 0.991
* Ctp = 760 * (273 + T) / P / 295 *

Drift			Irradiation		
Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere	Measurement time sec	Collected Charge, Q Coulomb	Current, I Ampere
100	0.002 nC		100	5.884 nC	
200	0.006 nC		100	5.868 nC	
			100	5.887 nC	
			100	5.880 nC	
			100	5.856 nC	
100	0.002 nC			$5.875 \pm 1.285 \times 10^{-2}$ nC	
100	0.002 nC				
	$2.4 \times 10^{-3} \pm 5.5 \times 10^{-4}$ nC				

Average Drift, $\bar{D} = 2.4 \times 10^{-3} \pm 0.55 \times 10^{-3}$ nC/100 Average Current, $\bar{I} = 5.875 \pm 1.28 \times 10^{-2}$ nC/100 sec

Signal, $S = (\bar{I} - \bar{D}) * Ctp * Ce$

Delivered Exposure Rate, $\dot{X}$ 6.608×10^{-3} R/s Chamber Response 1.125×10^{8} R/C

*** Chamber Response = $\dot{X}$ / S ***

NEUTRON FIELD MEASUREMENT USING A TISSUE–EQUIVALENT ION CHAMBER

Version: Feb. 15, 1991

Chamber (s/n) 610-KTC

Source (ID#) 241 Be - 7.2-1

Voltage +300

Distance 1. m

Electrometer(s/n & exp. date) 14356

Stop Watch(s/n & exp. date) Casio wrist watch

Electro. Corr., Ce 1.009

Operator Fred Krueger & Kamran Vaziri

Electro. Range 20 nCoul.

Measurement Date 2/13/92

Drift			Irradiation		
Meas. time, t (sec)	Collected Charge, Q (coul)	Current, I Q/t (Amp)	Meas. time, t (sec)	Collected Charge, Q (coul)	Current, I Q/t (Amp)
600	0.021 nc	3.50×10^{-14}	600	0.189 nc	3.150×10^{-13}
600	0.014 nc	2.33×10^{-14}	600	0.188 nc	3.133×10^{-13}
	$\bar{D} = 0.017_5$ nc		600	0.187 nc	3.117×10^{-13}
			600	0.198 nc	3.300×10^{-13}
			600	0.192 nc	3.200×10^{-13}
				$\bar{Q}_{ave} = (0.191 \pm 0.004)$ nC	

Ave. Drift, $\bar{D} = 2.917 \times 10^{-14}$ C/s Ave. Current, $\bar{I} = 3.180 \times 10^{-13}$ C/s

Signal, $S = (\bar{I} - \bar{D}) * Ce$

$= 2.888 \times 10^{-13} * 1.009 = 2.914 \times 10^{-13}$ C/s

Dose Equivalent Rate used for source above: 21.695 mrem/hr

PHOTON COMPONENT MEASUREMENT USING A GM COUNTER

Version: Feb. 15, 1991

GM Counter (s/n) GM525

GM Counter R/count 6.168×10^{-7} R/pulse

HV Supply (s/n) 1679 26

Voltage +500

Timer/Counter (s/n) IR007320

Neutron Source (ID#) 241Be-7.2-1

Source Rate, $\dot{H}$ ~21.695 mrem/hr

Distance 1.m, 0.5m

Operator

Date 2/20/92

Reading Number	Measurement Time (sec)	Reading (counts)	Count Rate, $\dot{R}$ (counts/sec)	$\dot{R}$ @1.m	
1	600	240	0.400	0.400	@ 1.m
2	300	518	1.727	0.432	@ 0.5m
3	300	445	1.483	0.371	@ 0.5m
4	300	499	1.663	0.416	@ 0.5 m
5	300	483	1.610	0.403	@ 0.5 m
				0.404±0.023	

Ave. Count rate, $\dot{R}$ = 0.404 Counts/sec @1.m Std. Deviation = 0.023 Counts/sec

Measured R/hr = (R/count) * $\dot{R}$ * 3600

= 6.168×10^{-7} R/count * 0.404 Counts/sec * 3600 = 8.971×10^{-4} R/hr

IC-1000 IONIZATION CHAMBER RESPONSE IN A PHOTON FIELD

Version: Feb. 15, 1991

Chamber (s/n) 610-KTC

Source (ID#) 137-3.5-1

Voltage +292

Distance 1. m

Electrometer(s/n & exp. date) 14356

Stop Watch(s/n & exp. date) CASIO wristwatch

Electro. Corr., Ce 1.009

Operator F. Krueger / K. Vaziri

Electro. Range 20nC

Measurement Date 2/20/192

Drift			Irradiation		
Meas. time, t (sec)	Collected Charge, Q (coul)	Current, I Q/t (Amp)	Meas. time, t (sec)	Collected Charge, (coul) Q-D	Current, I (Q)/t (Amp)
300	6.5×10^{-12}	2.2×10^{-14}	300	33.6×10^{-12}	1.12×10^{-13}
600	10.1×10^{-12}	1.7×10^{-14}	300	37.0×10^{-12}	1.23×10^{-13}
600	11.9×10^{-12}	2.0×10^{-14}	300	33.4×10^{-12}	1.11×10^{-13}
			600	66.0×10^{-12}	1.10×10^{-13}
					1.133×10^{-13}

Ave. Drift, $\bar{D} = 1.9 \times 10^{-14}$ C/s Ave. Current, $\bar{I} = 1.140 \times 10^{-13}$ C/s

Signal, $S = (\bar{I} - \bar{D}) * Ce$

$= 11.4 \times 10^{-14} * 1.009 = 11.52 \times 10^{-14}$ C/s

Exposure rate (R/hr) $1.256 \times 10^{-3} \div S \div 3600 = 3.034 \times 10^{6}$ R/C

PHOTON COMPONENT MEASUREMENT USING A GM COUNTER

Version: Feb. 15, 1991

GM Counter (s/n) GM525 — ~~Neutron~~ γ Source (ID#) 137-3.9-1

GM Counter R/count 6.168×10^{-7} R/pulse — Source Rate, $\dot{H}$ 1.256×10^{-3} R/hr

HV Supply (s/n) 933 05 — Distance as noted

Voltage +500 volts — Operator Fred Krueger / Kamran Vaziri

Timer/Counter (s/n) IR0073 20 — Date 2/20/92

	Reading Number	Measurement Time (sec)	Reading (counts)	Average Count Rate, $\dot{R}$ (counts/sec)
Drift	1	300	2	8.33×10^{-3} counts/sec
	2	300	3	
		@ 1.m		
Irradiation	1	600	375	5.97×10^{-1} counts/sec
	2	600	340	
	3	600	360	
		@ 0.5 m		
	1	300	675	
	2	300	670	2.28 counts/sec
	3	300	725	
	4	300	669	⇒@1.m $\dot{R} = 5.70 \times 10^{-1}$ counts/sec

Ave. Count rate, $\dot{R}$ = 5.77×10^{-1} pulses/sec Std. Deviation = 0.026 pulses/sec

Measured R/hr = (R/count) * $\dot{R}$ * 3600

= 6.168×10^{-7} R/pulse * 5.77×10^{-1} pulses/sec * 3600 = 12.812×10^{-4} R/hr